Omar, Mohd. Faizal and Trigunarsyah, Bambang and Wong, Johnny (2009) *Infrastructure project planning decision making : challenges for decision support system applications.* In: Proceedings of the 7th Asia Pacific Structural Engineering and Construction Conference & 2nd European Asian Civil Engineering Forum, 4-6 August 2009, Awana Porto Malai, Langkawi.

INFRASTRUCTURE PROJECT PLANNING DECISION MAKING: CHALLENGES FOR DECISION SUPPORT SYSTEM APPLICATIONS

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ABSTRACT
Most infrastructure project share the same characteristics in term of management aspects and shortcomings. Human factor is believed to be the major drawbacks due to the nature of unstructured problems which can further contribute to management conflicts. This growing complexity in infrastructure projects has shift the paradigm of policy makers to adopt Information Communication Technology (ICT) as a driving force. For this reason, it is vital to fully maximise and utilise the recent technologies to accelerate management process particularly in planning phase. Therefore, a lot of tools have been developed to assist decision making in construction project management. The variety of uncertainties and alternatives in decision making can be entertained by using useful tool such as Decision Support System (DSS). However, the recent trend shows that most DSS in this area only concentrated in model development and left few fundamentals of computing. Thus, most of them were found complicated and less efficient to support decision making within project team members. Due to the current incapability of many software aspects, it is desirable for DSS to provide more simplicity, better collaborative platform, efficient data manipulation and reflection to user needs. By considering these factors, the paper illustrates four challenges for future DSS development i.e. requirement engineering, communication framework, data management and interoperability, and software usability

Keywords: Infrastructure Planning, Decision Making, Decision Support System

1. INTRODUCTION

Physical infrastructure projects have been identified as a major factor to contribute the growth of economies in many countries. The growing complexities of modern construction projects consume a huge amount of construction capital and efficient coordination. Thus, the facilitation of project management aspects should be handled with great care. Otherwise, infrastructure project will tend to be cost overruns and benefit shortfalls [1]. Decision making has been highlighted as a major issue in infrastructure planning [2]. Nowadays, tools such as Decision Support System (DSS) have been developed to assist decision makers in construction project management. DSS are computer programs that aid users in problem solving or decision-making environment [3].

Many researchers have attempted to solve selection based problems in construction project management area by using DSS tools. However, most of the tools were complicated or lack of benefit and usability [4-10]. Due to this situation, those tools were found only concentrated on model development and left the fundamental essence of computing such as software engineering, information management and human centred computing.

In order to design a well established and mature DSS, we indentified four key issues / challenges of modern DSS in construction i.e. *requirement engineering*, *communication framework*, *data management and interoperability*, and *software usability.*

2. DECISION MAKING FOR INFRASTRUCTURE PROJECT

Decision making in infrastructure planning usually unstructured in form and it involved various parties [11]. Based on the behavioral decision theory, human judgment and decision making are characterized by biases, errors and the use of heuristics [12]. The problem of human judgment becomes more complex if it involves a group of people. A *decision group* is the term of a small, self regulating, self contained, task oriented work group that typically focuses on organizationally assigned decision making tasks [13]. The decision making procedure has to be performed through many negotiations among a group of decision makers. Due differences in individual interest, conflicts may arise and support for achieving consensus and compromise is required.

Research found that those problems were rooted as early as planning stage where there are too many alternatives and uncertainties were not entertained [14]. Meanwhile, Heijden [15] reported that most of the European countries experiences a rising complexities in infrastructures planning and it is difficult to manage. This is indicated by the trend of increasingly longer period of planning and decision making with respect to each projects. Some project may exceed up to ten years of planning stage due to several factors such as technical, financial, management bureaucracy, organisational affairs, culture, societal and political influences.

Traditionally, projects were dominated by classical engineer results in a mono-disciplinary approach with a focus on the technical engineering issues such as physical aspect and its use [16]. Thus, this approach had left the aspect of management and social evaluation.

Most of infrastructure projects around the world share the same characteristics in term of management aspects, shortcoming, cause of drawback and solutions [17]. Planning and decision making is often occur as a multi-actor processes with conflicting interest throughout project team. As a consequence, the communication and misinformation problems may arise among team member as the planning of infrastructure project will consume long time and efforts. Therefore, it is important to understand the fundamental concept of decision making process.

According to Simon [18], there are three phase of decision making which consist of intelligence, design, and choice. Later he added implementation as a fourth phase. Turban et. al. [3] recently refined Simon's model by inserted the aspect of monitoring/feedback (see Figure 1). The framework shows that there is a mechanism on modification/failure detection of decision making process. The system will be iterated back to the corresponding phase where the modifications/errors are detected. The decision making process starts with the intelligence phase where the reality (real world situation) is examined and the problem is identified and defined. There is a continuous flow of activity from intelligence to design to choice, but at any phase there may be a return to a previous phase (feedback). Formulation and modeling is essential for this process.

The problems of too many alternatives and uncertainties in infrastructure planning can be precisely modeled by using traditional technique such as decision-event approach or a more advanced technique i.e. system or decision support [19].

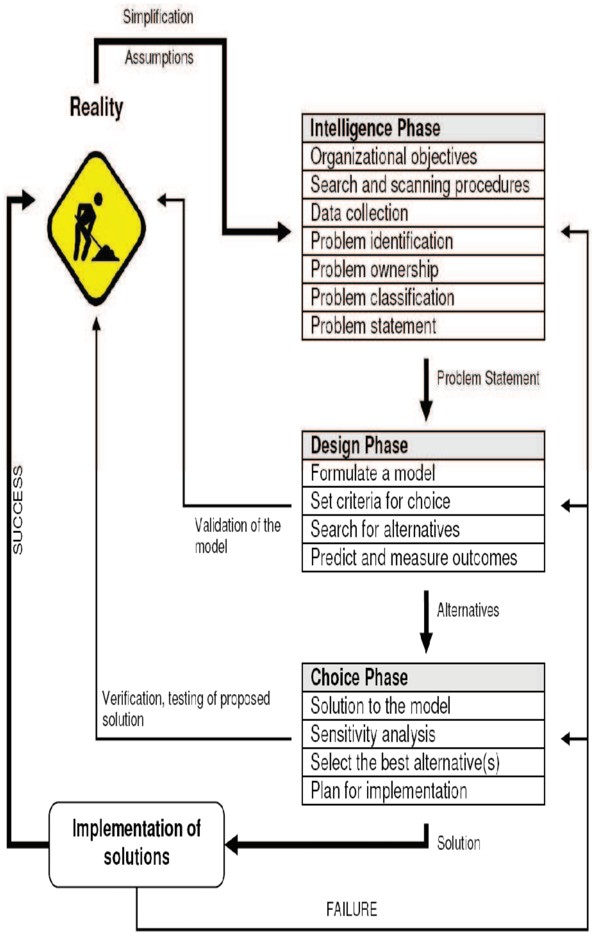

Figure 1 The decision making phase / modelling process (Simon [18] as adapted by Turban, Aronson, & Liang [3])

3. IMPORTANCE OF DECISION SUPPORT SYSTEM FOR INFRASTRUCTURE PLANNING

One of the most fundamental issues in the delivery of infrastructure concerns on what types of infrastructure are required and how they should be provided. The policy framework influenced the level of infrastructure provision and production and depends on policy objectives, the implementing institutions, levels and type of resources, knowledge, information and communication systems, and the environment [20]. This framework has shown that there is a need to adopt ICT as a driving force to enhance decision making within infrastructure planning (see Figure 2). Therefore, it is desirable that most managerial decision can be assist by the use of DSS tools.

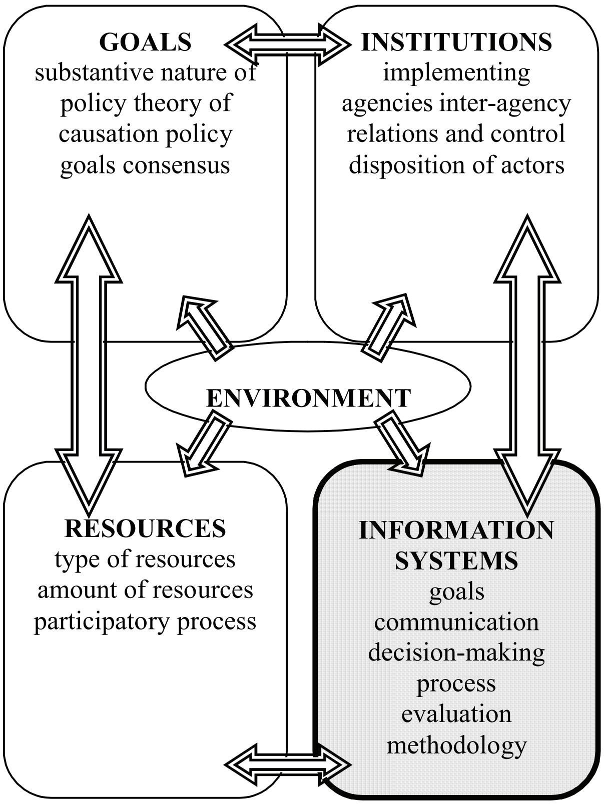

Figure 2 Elements of the policy making process

As mentioned before DSS are computer programs that aid users in problem solving or decision-making environment. DSS are gaining an increased popularity in various domains, including business, military, medicine, engineering and built environment [21].

The system have detailed knowledge, data, models, algorithms, user interfaces, and control mechanisms to support a specific decision problem [22]. They are valuable in situations in which the amount of available information is prohibitive for the intuition of an unaided human decision maker. Furthermore, DSS can aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, and aiding the process of structuring decisions.

DSS can also support choice among well-defined alternatives and build on formal approaches, such as the methods of engineering economics, operations research, statistics, decision theory and computer science [3]. They can also employ artificial intelligence methods to address heuristically problems that are intractable by formal techniques [23]. Thus, proper application of decision-making tools increases productivity, efficiency, and effectiveness and gives many businesses a comparative advantage over their competitors.

At planning stage, many criteria should be considered in order to choose the best alternatives. Therefore, this scenario can be considered as Multi Criteria Decision Making (MCDM). Much research on MCDM in construction has been conducted to date [4, 8, 24]. MCDM is widely used as a technique for DSS in construction management. Yet, most of the models were impractical as it is complicated or difficult for a layman such as project managers to use it [4-10].

Thus, by considering all the aforementioned reasons, it is desirable that those complexities in the DSS models can be easily hidden by an advanced DSS which can offer simplicity, effective and efficient tools towards better decision making for infrastructure planning

4. DSS DEVELOPMENT ISSUES

Hence, we identify four research issues: unstructured requirement engineering, lack of communication framework, vagueness of data management and interoperability, and disregard of software usability aspects.

4.1 Unstructured Requirement Engineering

According to Betty & Joanne [25], Requirement Engineering (RE) is the process by which the requirements of the software are determined. Successful RE involves understanding the needs of users, customers, and other stakeholders; understanding the contexts in which the to-be-developed software will be used; modelling, analysing, negotiating and documenting the stakeholder's requirements; validating that the documented requirements match the negotiated requirements and managing requirement evolution [25].

In other word, the success of a software system depends on how well it fits the needs of its users and its environments [26]. From this definition, it is obvious that the quality of software require a step-by-step or structured process of software development. To accomplish these tasks, a framework of RE process has been proposed in Figure 3.

However, it is founded that most DSS for selection based problem in construction project management do not employ a structured requirement engineering method as it is only concentrate on *requirement analysis* [4, 9, 10]. *Requirement analysis* is the concept of decision modelling which may comprise prioritization of alternatives [27]. Only a few of them attempt to adopt software engineering techniques [10].

However, it is still not enough to achieve a reliable and quality DSS. The lack of *software specifications* has led to unused model due to its failure to hide its complexity [28]. *Software specifications* may adopt few techniques from software engineering modelling such as Entity Relationship Diagram (ERD), Data Flow Diagram (DFD), Unified Modelling Language (UML), or even formal mathematical notations language [27].

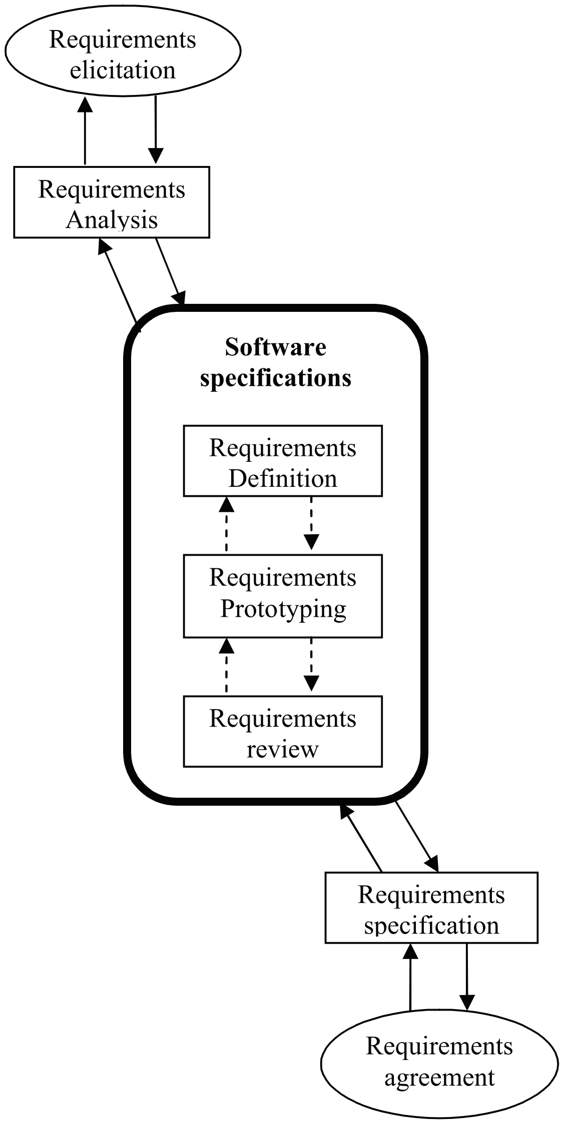

Figure 3 A requirement engineering process as adapted from Tsui & Karam [27]

4.2 Lack of Communication Framework

Communication is a vital element of DSS. Without communication, there is no collaboration. In a real world, individual decision makers must communicate with different stakeholders. However, due to the complexity of the project, conflicts may arise as group members possess different interest, views, and background [14]. To minimize conflicts, communication element must be added in DSS project management feature. Therefore, a Group Decision Support System (GDSS) is desirable to be considered as a solution due to its importance to strategic planning.

The effectiveness of a collaborative computing technology depends on the location of the group members and on the time that shared information is sent and received. A framework for classifying communication support technologies was proposed by DeSanctis and Gallupe [29]. Later, Turban et al. [3] added some recent technologies to the framework. Communication is divided into four cells, which are shown together with representative computerized support technologies in Figure 2. The four cells are organized along the two dimensions of time and place.

Table 1 Time/Place Communication Framework [3, 29]

	Same Time	Different Time
Same Place	• GDSS in a decision room • Web based GDSS • Multimedia presentation systems • Whiteboard • Document Sharing	• GDSS in a decision room • Web based GDSS • Workflow management system • Document Sharing • E-mail, V-Mail • Video conferencing playback
Different Place	• Web based GDSS • Whiteboard • Document sharing • Video conferencing • Audio conferencing • Computer conferencing • E-mail, V-Mail	• Web based GDSS • Whiteboard • Document sharing • E-mail, V-Mail • Workflow management system • Computer conferencing with memory • Video conferencing playback

As illustrated in Table 1, it is obvious that Web based GDSS has been superior to support decision making at any time and any place. However, only a few research in construction project management adopt web based DSS as an option [22], while the rest does not feature any communication capabilities in their development [6-8]. Nevertheless, some research has increasingly adopted web based DSS, yet still does not provide a sufficient platform specifically for group decision making [22].

4.3 Vagueness of Data Management and Interoperability

According to Turban et al. [3], Database Management System (DBMS) can be defined as a software program for adding information to a database and updating, deleting, manipulating, storing, and retrieving information. The design of the database should reflect the problem domain to be tagged. Donovan [30], suggest that there are five characteristics of problems to be considered through the use of a DSS which is 1) the problem is continuously changing, 2) the answers are needed quickly, 3) data are continuously changing, and come from a variety of sources, 4) data must be processed into different kinds of data representations, and 5) when computer support is required one is more concerned with rapid implementations than with long term efficiency. Unfortunately, there is some confusion about the appropriate role of DBMS and spreadsheets. This is because many DBMS offer capabilities similar to those available in spreadsheet such as Excel, and this enables DBMS user to perform DSS spreadsheet work with a DBMS [3]. Thus, the rich capabilities to support huge amount of data DBMS have been drawn out.

In DSS research, little attention has been devoted to database and data management particularly in MCDM based area [31]. In describing architectures of the database, it is depicted as a component but emphasis in on the model building aspects. There are two reasons for this [31]. First, data are collected for specific models and have not been regarded as a common resource for decision making. The second reason is data management is regarded as *back office* function and not unique to DSS. Later, a research reveal that only a few attempts has been made to leverage the capabilities of database features [32], however none consider a datatabase which can support a multicriteria specifically for group decision making [4, 9].

Therefore, there are needs to provide a framework to design a robust database for data collection and manipulation specifically in DSS. Furthermore, the framework should also encompass the integration and interoperability with existing system such that no system is isolated.

4.4 Disregard of Software Usability Aspects

The rapid expansion of the software applications has brought software usability engineering into prominence. As more and more information exists in electronic form, the storage and retrieval of information is increasingly a Human Computer Interface (HCI) design problem [33]. As the DSS become complex by the nature of its models, user-centred design (UCD) increasingly important for software development to consider the aspect of usability [33]. Usability determines how effectively and comfortably an end user can achieve the goals that gave rise to an interactive system [34]. In addition, usability relates on how the system interacts with the user, and it includes five basic attributes i.e. learnability, efficiency, user retention over time, error rate, and satisfaction [35].

The implementation of DSS should balance between the software requirements and human aspect. As illustrated in Figure 4, a good framework that bridge the practices in user-centred and software engineering has been introduced by IBM and later adapted by Seffah & Metzker [33]. Thus, the best practice of software development is to balance and sit in the middle between those two distinct areas.

By these reasons, it is desirable that DSS should incorporate human factor in its development. Instead of the validation of consistency model checking, it is also important that the software should be verified by users for its usefulness. Many of research in this area discarded the aspect of human computing and there is no evaluation by the user on how good the system been implemented [10, 32, 36-38].

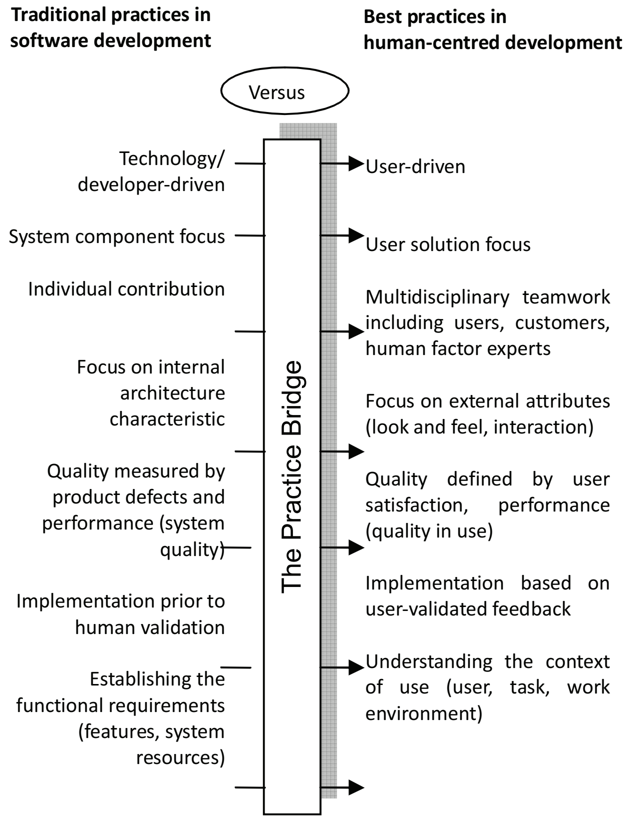

Figure 4 Practices in user-centred and software engineering

4. CONCLUSIONS AND FUTURE WORKS

Public infrastructure projects are sophisticated and dynamic in nature. Human factor is believed to be the major drawbacks due to the nature of unstructured problems which can further contribute to management conflicts. This growing complexity in infrastructure projects has shifted the paradigm of policy makers to adopt ICT as a driving force. Therefore, a lot of tools have been developed to assist decision making in construction project management. The variety of uncertainties and alternatives in decision making can be entertained by using useful tool such as DSS. However, the recent trend shows that most DSS in this area only concentrated in model development and left few fundamentals of computing. Thus, most of the tools were complicated and lack of benefits to support decision making within project team members.

This paper has presented four key issues i.e. unstructured requirement engineering, lack of communication framework, vagueness of data management and interoperability, and disregard of software usability aspects.

This paper provides a preliminary study of DSS and the work will progress on the development of DSS for consultant selection in public sector. Unaided decision making particularly for consultant selection has been identified as a problem in Malaysian water management. Thus, this will become our trigger to develop an efficient and effective DSS.

5. REFERENCES

1. Flyvbjerg, B., *Policy and planning for large-infrastructure projects: problems, causes, cures.* Environment and Planning B: Planning and Design, 2007. **34**(4): p. 578-597.
2. Goodman, A.S. and M. Hastak, *Infrastructure planning handbook : planning, engineering, and economics*. 2006, New York :: ASCE Press ; McGraw-Hill. 1 v. (various pagings) :.
3. Turban, E., J.E. Aronson, and T.P. Liang, *Decision Support Systems and Intelligent Systems*. 7th ed. 2005, Upper Saddle River, New Jersey: Prentice Hall.
4. Shapira, A. and M. Goldenberg, *AHP-based equipment selection model for construction projects.* Journal of Construction Engineering and Management-Asce, 2005. **131**(12): p. 1263-1273.
5. Al-Besher, M.F.S., *A conceptual model for consultant selection in Saudi Arabia*, in *Faculty of the College of Graduate Studies*. 1998, King Fadh University of Petroleum & Minerals: Dhahran.
6. Chow, L.K. and S.T. Ng, *A fuzzy gap analysis model for evaluating the performance of engineering consultants.* Automation in Construction, 2007. **16**(4): p. 425-435.
7. Ibrahim, M.M., et al., *A multi-criteria approach to contractor selection.* Engineering Construction and Architectural Management, 2002. **9**: p. 29-37.
8. Kahraman, C., U. Cebeci, and Z. Ulukan, *Multi-criteria supplier selection using fuzzy AHP.* Logistics Information Management, 2003. **16**(6): p. 382-394.
9. Manoharan, R., *Subcontractor Selection Method Using Analythic Hierarchy Process*. 2005, Universiti Teknology Malaysia.
10. McCowan, A.K. and S. Mohamed, *A classification of Decision Support System for the analysis and evaluation of concession project investment.* Journal of Financial Management of Property and Construction, 2002. **7**(2): p. 127-137.
11. Vanier, D.J., *Decision support systems in infrastructure management.* ITcon, 2006. **11**: p. 175-176.
12. Nisbet, R. and R. Ross, *Human Inference: Strategies and Shortcomings of Social Judgement*. 1980, Englewood Cliffs, NJ: Prentice-Hall.
13. Alavi, M. and P.G.W. Keen, *Business teams in an information age.* Information Society, 1989. **6**(4): p. 179-195.
14. Niekerk, F. and H. Voogd, *Impact assessment for infrastructure planning: some Dutch dilemmas.* Environmental Impact Assessment Review, 1999. **19**(1): p. 21-36.
15. Heijden, R.V.d., *Planning large infrastructure projects : seeking a new balance between engineering and societal support.* Dokumente und Informationen zur Schweizerischen Orts-, Regional- und Landesplanung (DISP), 1996. **32**(125): p. 18-25.
16. Perez, A.I. and A.K. Ardaman, *New infrastructure: Civil engineer's role.* Journal of Urban Planning and Development, 1988. **114**(2): p. 61-72.
17. Flyvbjerg, B., *Design by deception*, in *Harvard Design Magazine*. 2005. p. 50-59.
18. Simon, H., *The New Science of Management Decision*. 1977, Englewood Cliffs, NJ: Prentice Hall.
19. Schmidt, R.L. and J.R. Freeland, *Recent progress in modeling R&D project-selection processes.* IEEE Transactions on Engineering Management, 1992. **39**(2): p. 189-201.
20. Howes, R. and H. Robinson, *Infrastructure for the built environment : global procurement strategies*. 2005, Oxford ; Burlington, MA :: Elsevier Butterworth-Heinemann. xxii, 327 p. :.
21. Eom, S. and E. Kim, *A survey of decision support system applications (1995-2001).* Journal of the Operational Research Society, 2006. **57**(11): p. 1265-1278.
22. Bhargava, H.K. and C. Tettelbach, *Web-based decision support system for waste disposal and recycling.* Computers, Environment and Urban Systems, 1997. **21**(1): p. 47-65.
23. Eom, S.B., *The contributions of systems science to the development of the decision support system subspecialties: An empirical investigation.* Systems Research and Behavioral Science, 2000. **17**(2): p. 117-134.
24. Ibrahim, M.M., et al., *A multi-criteria approach to contractor selection*. 2002. p. 29-37.
25. Betty, H.C.C. and M.A. Joanne, *Research Directions in Requirements Engineering*, in *Future of Software Engineering (FOSE '07)*. 2007.
26. Bashar, N. and E. Steve, *Requirements engineering: a roadmap*, in *Conference on The Future of Software Engineering*. 2000. p. 35-46.
27. Tsui, F. and O. Karam, *Essentials of software engineering*. 2007, Sudbury, Mass. :: Jones and Bartlett Publishers. xiv, 384 p. :.
28. Qijia, T., et al., *An organizational decision support system for effective R&D project selection.* Decision Support Systems, 2005. **39**(3): p. 403-413.
29. DeSanctis, G. and B. Gallupe, *Group decision support systems: a new frontier.* SIGMIS Database, 1984. **16**(2).
30. Donovan, J.J., *Database system approach to management decision support.* ACM Transactions on Database Systems, 1976. **1**(4).
31. Methlie, L.B., *Data management for decision support systems.* SIGMIS Database, 1980. **12**(1).
32. Spainhour, L.K., P.V. Mtenga, and J. Sobanjo, *Multicriteria DSS with Historical Database for Attenuator Selection.* Journal of Computing in

Civil Engineering, 1999. **13**(3): p. 187-197.

33. Seffah, A. and E. Metzker, *The obstacles and myths of usability and software engineering.* Communications of the ACM, 2004. **47**(12): p. 71-76.
34. Bass, L., B.E. John, and L. Bass, *Supporting Usability Through Software Architecture.* Computer, 2001. **34**(10): p. 113-115.
35. Nielsen, J., *Usability Engineering*. 1995, San Francisco: Morgan Kaufmann Publishers Inc. 362.
36. Kumaraswamy, M.M. and S.M. Dissanayaka, *Developing a decision support system for building project procurement.* Building and Environment, 2001. **36**(3): p. 337-349.
37. Shen, Y.C. and D.A. Grivas, *Decision-Support System for Infrastructure Preservation*. Journal of Computing in Civil Engineering, 1996. **10**(1): p. 40-49.
38. Molenaar, K.R. and A.D. Songer, *Web-based decision support systems: Case study in project delivery.* Journal of Computing in Civil Engineering, 2001. **15**(4): p. 259-267.